1896MNRAS..56..459S

found convenient to duplicate the lever E F, and place half or a certain portion of the counterpoise at the end of each duplication, so as to keep the counterpoise clear of the polar axis and its arm in every position.

On the Importance of Accurately Observing the Leonids this Year.

By G. Johnstone Stoney, M.A., D.Sc., F.R.S.

The *Leonids*, the great November swarm of meteors, is the meteoric stream about which astronomers know most.

This great body of meteors traverses an immense oval orbit which, near its farther apse, crosses the path of the planet *Uranus*, and near its perihelion crosses the earth's path. The meteoric orbit does not intersect the orbits of the intermediate planets, *Saturn*, *Jupiter*, and *Mars*, owing to the considerable inclination of its plane. Round this great inclined orbit the meteors glide in a stream which lengthens as it moves inwards towards the Sun, and becomes shorter during each outward journey. Where the swarm passes the Earth it is about 100,000 miles thick, and of such a length that, though it travels at the rate of 27 miles a second, the great procession takes two years to pass us, and when its hinder part is still with us, its front will have reached to between the orbits of *Jupiter* and *Saturn*. Nevertheless, although so immensely long, it extends over only a portion of the circumference of its own great orbit, which it takes about a third of a century to traverse.

The front of this great swarm will next reach the Earth's orbit late in the spring of 1899. The Earth will then be in a distant part of its orbit, but in the middle of the following November and in November 1900 it will pass obliquely through the mighty stream, and on each of these occasions there will be an astounding rain of meteors, probably for about five hours, on the whole of the advancing side of the Earth.

Now, when we have regard to the fact that these meteors are not visible in outer space, and that we can only, and only for a second or two, observe that small proportion of them which happen to flash into some part of our small atmosphere, it is truly astonishing that it has been possible to gain so much knowledge of their movements and history.

Astronomers may be divided into two classes—chamber astronomers and observers. Sir Isaac Newton was the greatest of the former class, and the late Professor Couch Adams was one of the greatest of modern times. To him and to Professor H. A. Newton, of New Haven, we chiefly owe the great discovery. Before the visit of the meteors to the Earth in 1866 and 1867, Professor Newton pointed out how to deal with the problem, but it was by a process so difficult that it remained doubtful whether

1896MNRAS..56..459S

any mathematician could successfully grapple with it. He also called the attention of practical astronomers to a datum which was wanted and which could be supplied by observation. Owing to his forethought, the requisite observations were made on the morning of 1866 November 14 (civil time), and immediately afterwards Professor Adams set to work to employ the material so furnished in the way that Professor Newton had indicated. In the following May, after five months of arduous labour, he was able to announce what the real orbit of the meteors is.

The *Leonids* are at present advancing inwards towards the Earth. They cannot be seen, but their position can be calculated, and it would be possible to determine to what part of the Earth's orbit they present themselves most endlong. Though not visible to the eye, it is quite possible that they may be photographed, and we have among us astronomers especially competent to make the attempt.

There is a comet in the track of these meteors. It will reach its perihelion before them. All the information about this comet which industry can glean from former observations should be thoroughly elaborated and put together in time to make full use of it when the comet reappears; and when that occurs all the elements of the comet's orbit, and, if possible, its apsidal motion, should be determined with the utmost precision, to aid in tracing whether the comet was once perturbed by the Earth, like the stray *Leonids* seen annually. Whatever knowledge, too, spectroscopic scrutiny would furnish may prove of use.

A desideratum of special theoretical importance, and one which requires that observers should at once be on the alert, is as exact a determination as possible of the day and hour of apparition, and of the path in our atmosphere, of such outlying portion of the swarm as may precede the principal stream or follow it by one or more years. On the last occasion observations of this kind were made chiefly after the great visitation had taken place. It is of importance that on this occasion equally full observations shall be made in the years preceding it, *i.e.* in the present year and in 1897 and 1898. It is desirable that, wherever possible, concerted observations shall be made from different stations; that they be much more exact than heretofore, and therefore made photographically when possible; also, that they shall extend to a few days before and a few days after the 14th and 15th of November, inasmuch as we do not yet know on what dates to expect the advent of the avant-couriers of the principal swarm.

It is necessary here to keep in view the distinction between real advanced members of the great swarm, and mere scattered *Leonids*, a few of which are seen every year. The true forerunners of the swarm will, presumably, present themselves only within a brief definite period of time, extending to something like five hours, whereas a sprinkling of sporadic meteors may be met with for several days. These stray meteors seem to be meteors near to which the Earth chanced to pass in one or other

1896MNRAS..56..459S

of its transits through the swarm, and which were by the Earth deflected a little from the true meteoric orbit. It does not appear that any special use can be made of observations upon these scattered *Leonids*.* But accurate observations of the true avant-couriers are specially wanted, and the importance of these observations will appear from what follows.

We come now to the chief matter which should be kept in view. The meteors are not a compact cluster, but drawn out along a considerable portion of their orbit. This, as Schiaparelli pointed out, is consequent upon there being differences between the periodic times of the individual meteors. Those that come round fastest get ahead, those that have the longest periodic time lag behind. Thus the stream is one that is lengthening century after century, and we can look back to a time when the whole must have been a compact cluster.

Now there is reason to conjecture that it was in the early spring of the year A.D. 126 that this lengthening out of the group commenced; for Le Verrier discovered that in the end of February or beginning of March of that year the meteors and the great planet *Uranus* were both at the point where their orbits intersect —an event which has not happened since. This raises a well founded suspicion that up to that year the meteors may have been a compact cluster travelling inwards towards the Sun; that in that year they stumbled on this great planet; and that it remained long enough in their vicinity to exercise such an influence over them as drew them out of their previous course and started them in the new orbits round the Sun, which they have since for nearly eighteen centuries pursued. If it acted in this way the planet would inevitably perturb the several members of the group a little differently, so that their new orbits would not be precisely the same. If, in consequence of this their periodic times vary from a week more to a week less than the mean periodic time (which mean is about thirty-three years and a fifth), just that extension of the group which we actually observe would have had time to develop in the fifty-three revolutions that have since taken place.

It is most desirable that everything that it is possible to do shall be done to test this remarkable theory. It seems to be possible to test it, for, owing to the perturbation of their elliptic motion by the planets, the orbits of the meteors suffer an apsidal shift which is easily observed, and which, in fact, retards the date on which the great meteoric showers take place by a considerable amount every century. This is almost wholly owing to the attraction of the great planets *Jupiter* and *Saturn*. *Uranus*

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* There is, however, one notable exception. We have reason to suspect that the comet is one of the bodies whose motion was perturbed by the Earth. Accurate observations of the comet should determine whether this is so; and if it prove to be the case, it should be possible further to determine when the catastrophe occurred, by tracing back the comet's course and the Earth's till we come to a time when they were near to one another.

1896MNRAS..56..459S

produces a perceptible but trifling effect, and the influence of the Earth and the other planets is insensible. Now it so happens that the periodic time of the meteors is related in a very remarkable way to those of *Jupiter* and *Saturn*, being nearly nine-eighths of the periodic time of *Saturn*, and still more nearly fourteen-fifths of the periodic time of *Jupiter*. Accordingly, in the fifty-three revolutions of the meteors which have taken place since A.D. 126, *Saturn* and they have six times repeated somewhat similar cycles of relative positions, each, moreover, *of a very special character* ; and *Jupiter* and they have ten times repeated almost exactly the same cycle of relative positions. Now, where simple numerical relations of this kind subsist, the situation of a meteor along the orbit—viz. whether it is near the head or the tail of the meteoric stream, still more if it be an outlying meteor in front or behind—is likely to have an appreciable effect on the apsidal shift which its orbit suffers. It is, therefore, of great importance to determine whether any such differences between the apsidal shift of meteors variously situated can be observed, in order that the observed amounts may be compared with those calculated on the supposition that Le Verrier's hypothesis is true. If the calculated and observed amounts accord, Le Verrier's hypothesis will be proved ; if they do not accord, it will be disproved : in either case we shall know more about the history of the meteors than we do now.

Hence the great importance of this year commencing the task of determining the exact radiant points of different portions of the swarm, and the approximate times of their apparition in our atmosphere, so as to furnish to mathematicians the requisite data for their calculations. In this work it is obvious that eye observations should, as far as possible, be replaced by photographs.*

Galactic Longitude and Latitude of Poles of Binary-Star Orbits.

By Alice Everett.

The data upon which the accompanying table is founded are not satisfactory. In the case of a very few stars there seems little doubt that the orbit determined is substantially correct, and in the case of a few more the elements obtained by different computers show some agreement. These will be recognised in the list by those familiar with the subject. But the greater number of orbits computed seem to be very uncertain.

From the results, such as they are, it does not seem that any decided tendency on the part of the poles of the orbits to favour any special region of the sphere can reasonably be deduced. (See summary appended to tables.)

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* A popular account of the discoveries made in connection with the last visit of the November meteors will be found in the Journal of the Royal Dublin Society of 1869 April 3, and in the Proceedings of the Royal Institution of 1879 February 14; and appended to it there is a list of the original memoirs in reference to the advances which were then made.